Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matters of	)	
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Mitigation of Orbital Debris in the New Space Age	)	IB Docket No. 18-313
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Mitigation of Orbital Debris	)	
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Notice of Proposed Rulemaking and Order on Reconsideration	)	

COMMENTS OF KEPLERIAN TECHNOLOGIES INC.

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April 5, 2019

EXECUTIVE SUMMARY

Keplerian Technologies, Inc. ("KTi") is an emerging global leader in developing "Space Situational Awareness" ("SSA") solutions to monitor, track and predict the location of space objects. KTi submits these comments to highlight the critical importance of SSA capabilities to minimize the release of orbital debris and preserve the integrity and utility of increasingly congested orbits critical for commercial, military and scientific space operations.

The effective collection of SSA data promotes healthy orbital lanes, and gives operators the means to timely and accurately react to potential collision events. To promote critical SSA capabilities, KTi urges the Commission to require commercial spacecraft and foreign spacecraft operators seeking United States market access to implement independent transponder and tracking capabilities. The implementation of onboard transponders will dramatically improve the accuracy of and access to SSA data, which will ultimately facilitate applications and analytics that mitigate collisions, improve satellite operator efficiency, and lower insurance premiums across the industry.

The Commission should limit SSA data sharing to essential datasets that allow for accurate and timely tracking and collision avoidance. Specifically, satellite operators and transponder providers should only be required to share three-dimensional position and velocity data. A limited data-sharing requirement promotes public interests while recognizing the proprietary rights of commercial operators/owners.

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Keplerian Technologies, Inc. ("KTi") submits comments in support of select issues raised by the Federal Communications Commission ("Commission") in the above-referenced proceeding.[1] Specifically, KTi highlights that enhancing "Space Situational Awareness" is critically important to collision avoidance, an essential factor for mitigating orbital debris. As such, solutions like that offered by KTi allowing for tracking spacecraft through an independent transponder, similar in function and purpose to those served by "black boxes" in airplanes, is crucial to achieve the policies identified by the Commission in this proceeding. Additionally, the Commission should mandate obtaining, maintaining and sharing select tracking datasets post-mission and in the event of failure for the reasons identified herein, while also protecting the proprietary and confidential nature of such data. KTi also emphasizes that tracking solutions would decrease insurance premiums, making policies more affordable and incentivizing operators to actively mitigate collision risks. Finally, KTi recommends that any rules promulgated by the

[1] *See Mitigation of Orbital Debris in the New Space Age; Mitigation of Orbital Debris*, Notice of Proposed Rulemaking and Order on Reconsideration, IB Docket No. 18-313, 33 FCC Rcd 11352 (2018) ("Orbital Debris Mitigation").

Commission based on this proceeding apply to all operators that seek access to the U.S. market. Establishing a common set of rules enhances the benefits of space for all participants and helps ensure that highly desired orbital planes retain their utility as innovative new space-based services develop.

I. BACKGROUND

Orbital debris is already a significant issue capable of damaging or destroying existing spacecraft and threatening the proposed deployments of both large broadband satellite constellations and innovative smaller spacecraft. Indeed, like modern highways on land, sea, and air around densely populated areas, orbiting satellites are facing their own form of "orbital highway" congestion.[2] As the Commission recognizes, there are "estimated to be 500,000 pieces of debris the size of a marble or larger, and many millions of pieces of debris that are so small they cannot be tracked."[3] However, unlike land, sea, and air highways, satellites in orbit must navigate these increasingly congested orbital highways with great uncertainty. The majority of satellite operators have little to no timely situational awareness of the adjacent satellite population and must often deal with untimely traffic reporting while facing the reality that they have minimal ability to maneuver satellites to avoid collisions with debris or other satellites.

While space is vast, available orbits are finite. Already three collisions have occurred since 2009 between either pairs of operating satellites or satellites and debris. Spacecraft breakups and collisions greatly increase the amount of orbital debris.[4] By the end of this decade, the number and diversity of "New Space" commercial ventures operating around the Earth will see an order of

[2] *See id.* at 11356-57, paras. 8-9.

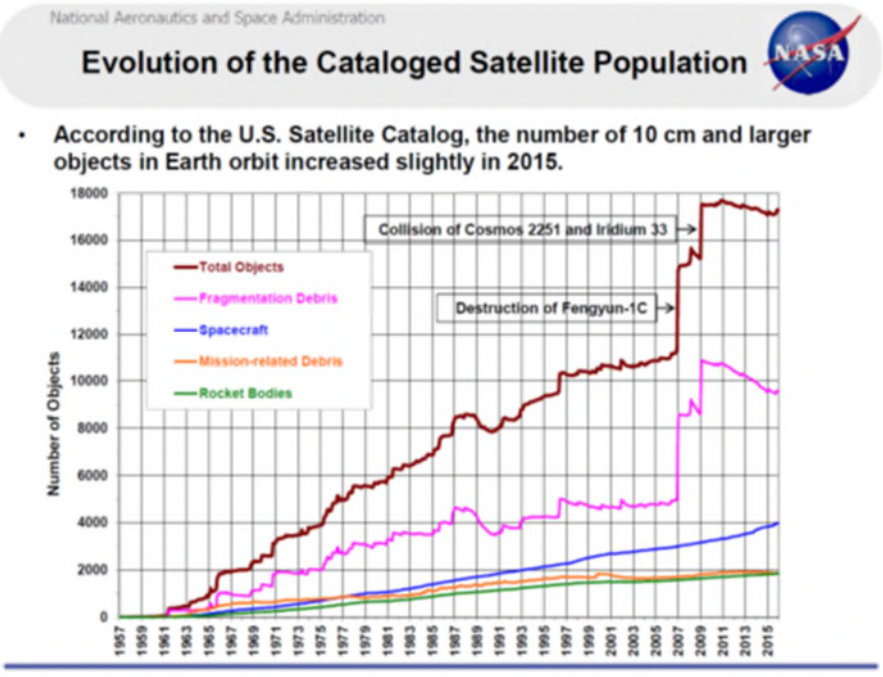
[3] *See id.* at 11356, para. 8.

[4] *See, e.g., id.* ("[F]ragments associated with the intentional fragmentation of the Fengyun 1C spacecraft in 2007 and the accidental collision of the Cosmos 2251 spacecraft with the commercial Iridium 33 spacecraft in 2009 account for over 25% of cataloged on-orbit space objects.").

magnitude increase in the number of satellite operating in specific orbital regions at less than 1,800 km altitude.

The rapid proliferation of spacecraft has heightened orbital safety concerns for potential collisions between two space objects adversely affecting not only the U.S. but the entire international community. However, as the Commission rightly highlights, the risk disproportionately falls on the U.S. due to our nation's commanding lead in space commerce and orbital launch activities.[5]

There are a number of factors increasing the risks of more frequent orbital conjunctions and potential on-orbit collisions. First, the rate of production of orbital debris is rapidly growing. Figure 1 below illustrates the growth of the space object population over the past 50 years and the significant increase in orbital clutter that resulted from recent debris-causing events.



[5] "The United States leads the world in space commerce, totaling approximately 57 percent of global space spending, and accounting for one-third of all orbital launch activities." *Id.* at 11353, para. 1.

Next, the advent of new technologies enabling smaller satellites based on a CubeSat form factor has drastically reduced launch costs resulting in a greater quantity of spacecraft in orbit.[6] This trend will continue as detailed below. Additionally, the use of non-impulsive maneuvering, *i.e.*, spacecraft with active propulsion, complicates orbit prediction. Inexperienced satellite operators also contribute to increase collision and fragmentation risks.

Figure 2 below illustrates the enhanced probability of satellite collisions based on increased space debris and satellites:

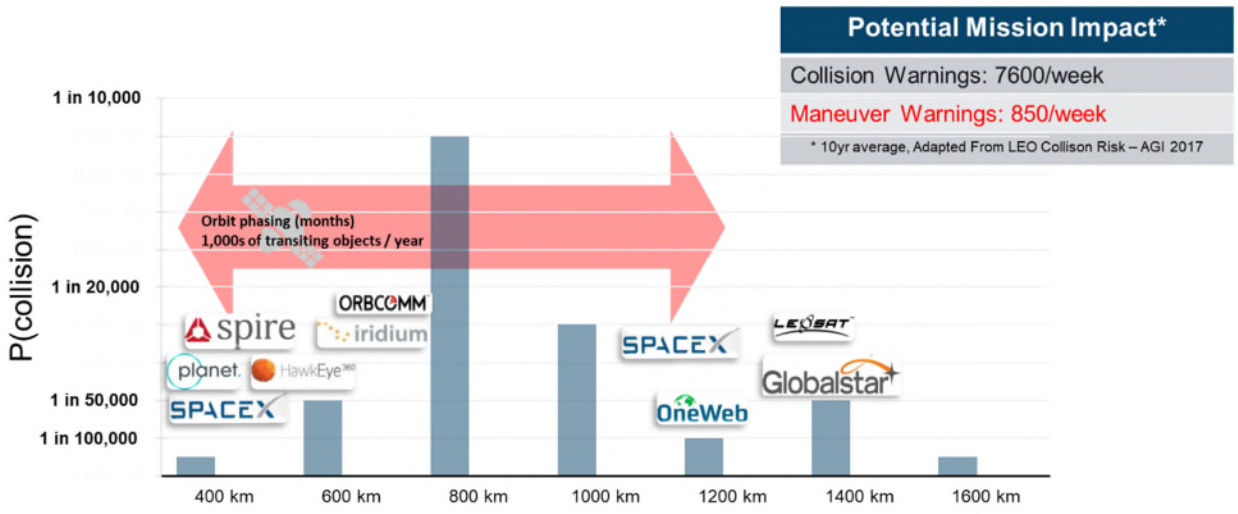


Figure 2: LEO Probability of Collision

Moreover, the use of commercial grade components and more commercial-driven business practices will likely lead to an increase in the number of non-operational spacecraft. Already historic data demonstrates that of the first 100 small satellites launched (between 2000 and 2012), 17 failed in the first ten days of orbit, with another nine failing in the first 100 days of orbit.[7]

[6] *See id.*

[7] Michael Swartwout, *The First One Hundred CubeSats: A statistical look*, 2.2 Journal of Small Satellites 213, 220-23 (2013).

The problem is only getting worse as the population of small satellites is accelerating. Between the years 2012 and 2017, governments and private interests deployed over 1,000 small satellites collectively. In 2017 alone, the number of launches exceeded those in 2012 by a factor of six. The launch rate in 2021 could more than double that of 2017 with the potential influx of commercial "mega-constellations."

While only two significant debris-causing events have occurred over the past 50 years,[8] some studies predict that one collision will occur per year between tracked non-maneuvering space objects and debris greater than 1 cm size in the Low Earth Orbit ("LEO") region.[9] As the Commission recognizes, "orbital debris objects greater than one centimeter in diameter can cause catastrophic damage to functional spacecraft."[10] Although impossible to predict, a single collision between two space objects could result in significant deleterious impacts to both commercial and national security interests for decades to come. The National Academy of Sciences *National Security Space Defense and Protection* report details the importance of space systems to the nation and world:

> "Space systems—systems with one or more components resident on Earth-orbiting satellites—are integral parts of the national and global information infrastructure. Some of these systems are essential parts of that infrastructure in that their functions either cannot be performed solely by terrestrial systems or can only be performed poorly and/or with great difficulty and expense by land, sea, or air-based substitutes. In the abstract, were all of the space systems suddenly to shut down, the global information infrastructure would cease to function as the world has come

[8] India's anti-missile test on April 1, 2019, likely represents a third event creating meaningful orbital debris, but definitive data on this incident may not be available until later in 2019. *See* NASA, *Town Hall with NASA Administrator Jim Bridenstine*, (April 1, 2019) https://images.nasa.gov/details-NHQ_2019_0401_Town%20Hall%20with%20NASA%20Administrator%20Jim%20Bridenstine.html.

[9] Science Applications International Corporation, *Orbital Traffic Management Study Final Report, Prepared for NASA Headquarters*, 5 (Nov. 21, 2016) ("SAIC Orbital Traffic Management Study").

[10] Orbital Debris Mitigation, 33 FCC Rcd at 11356, para. 8.

> to expect; were the use of space to be denied in perpetuity, current information capabilities would be nearly impossible to reconstruct."[11]

For the current and future space industry to continue to grow and thrive, it is vital to minimize space traffic risks.

II. ENHANCING SITUATIONAL AWARENESS IS VITALLY IMPORTANT

Monitoring, tracking, and predicting the location of space objects, referred to as "Space Situational Awareness" or "SSA," is the primary means to prevent on-orbit collisions and preserve the space environment. Currently, the U.S. government, through the Department of Defense's Combined Space Operations Center ("CSpOC") primarily provides SSA capabilities and collision warning notifications to government and private spacecraft operators. The CSpOC is responsible for space object monitoring, tracking, and orbit prediction, as well as notifying both government and commercial satellite owner-operators of potential on-orbit conjunctions (potential collisions). In 2015, the Department of Defense provided 1,297,891 conjunction notifications to spacecraft owner-operators, representing a 93 percent increase over 2016.[12]

As space becomes increasingly congested and contested with the surge in commercial space companies, new commercial operators and launch providers, SSA and space traffic management is quickly becoming an important policy area for the U.S., its allies, and commercial partners. In particular, the increasing number of space objects presents challenges for the safety, stability, and sustainability of U.S. space operations. While SSA has primarily been the job of the United States Air Force, Space Policy Directive ("SPD-3") has directed new policy changes that will enhance the U.S. government's SSA capabilities and extending such to other executive

[11] National Academies of Science, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report (2016)*, 2 (Aug. 2016).

[12] *See* 18 SPCS Mission Brief, Air Force Space Command, Lt Col. Scott Putnam, 26; SAIC Orbital Traffic Management Study, D-3.

agencies. Ultimately, SPD-3 envisions a bifurcation of functions such that the Department of Defense performs SSA and space-traffic-management functions for the U.S. military, allowing it to focus on protecting and defending U.S. space assets and interests due to the increased contested nature of space, while federal executive agencies perform such tasks for the rapidly growing commercial space enterprise.[13] As recognized in SPD-3, SSA and space traffic management have become an increasingly important component of protection national security:

> "To maintain U.S. leadership in space, we must develop a new approach to space traffic management (STM) that addresses current and future operational risks. This new approach must set priorities for space situational awareness (SSA) and STM innovation in science and technology (S&T), incorporate national security considerations, encourage growth of the U.S. commercial space sector, establish an updated STM architecture, and promote space safety standards and best practices across the international community."[14]

The ever-increasing space object population overtaxes and stretches U.S. government SSA capabilities and presents an increasing burden on government resources to identify and track orbiting objects of interest. The coming spike in commercial spacecraft operating in the LEO will dramatically increase the number of collision warnings, quickly overwhelming the existing Department of Defense's SSA systems. An independent assessment by Aerospace Corporation concluded that large LEO constellations, like those proposed by new commercial space companies, could significantly increase collision warnings to owner-operators predicting conservatively that, for a 4,000 plus spacecraft constellation, 64 million collision warnings per year were potentially possible *just for the spacecraft among such a constellation.*[15]

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[13] *See* Space Policy Directive-3, National Space Traffic Management Policy, Presidential Memoranda, Section 1 (June 18, 2018) https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/.

[14] *Id.*

[15] *See* Peterson, Glen, et al., *Implications of Proposed Small Satellite Constellations on Space Traffic Management and Long-Term Debris Growth in Near-Earth Environment*, 67th

This flood of conjunction warnings could quickly paralyze commercial ground operations teams likely resulting in the lack of timely action for individual spacecraft. For example, mega-constellations (1,000-5,000 satellites) must devise maneuvering strategies to traverse from their initial injection orbits to their operational orbits and back again at end of life. As recent conjunction impact assessments from the introduction of mega-constellations predicts that typical New Space LEO operators can anticipate receiving 3 km conjunction warning messages on the order of 300-5,000 per week and 1 km maneuver warning messages from 35-560 per week.[16] This number of warning messages is unprecedented in the flight operations community and raises serious operational, mission impact and cost concerns for commercial operators.

III. THE COMMISSION SHOULD REQUIRE SPACECRAFT INCLUDE INDEPENDENT TRANSPONDER AND TRACKING CAPABILITIES

To increase the sustainability of LEO, the United Nations Committee on the Peaceful Use of Outer Space ("UN COPUOS") has encouraged member states to enhance the tracking of spacecraft through design considerations. Specifically, UN COPUOS recommends that member states should:

> "[P]romote design approaches that increase the trackability of space objects, including small size space objects, regardless of their physical and operational characteristics, including small-size space objects, and those that are difficult to track throughout their orbital lifetime, as well as facilitate the accurate and precise determination of their position in orbit."[17]

International Astronautical Congress, Guadalajara, Mexico, Sept. 2016; Peterson, Glen, et al., *Effect of CubeSats on Collisions and Long-Term Debris Growth in Near-Earth Environment*, 67th International Astronautical Congress, Guadalajara, Mexico, Sept. 2016; SAIC Orbital Traffic Management Study, F-2.

[16] Dan Oltrogge, AGI COMSPOC, *LEO Collision Risk*, 14 (Apr. 27, 2017).

[17] United Nations Committee on the Peaceful Use of Outer Space, Scientific and Technical Subcommittee, Fifty-fifth session, *Long-term sustainability of outer space activities*, Guideline 30, A/AC.105/C.1/2018/CRP.18/Rev.1 (Feb. 8, 2018).

Likewise, the Commission has recognized that the "identification of satellites and sharing of tracking data are important to provide timely and accurate assessments of conjunction with other spacecraft."[18]

While the administrative components proposed by the Commission serve an important purpose, technical solutions are critical as well. To this point, the Commission is considering requiring applicants to "certify that the satellite will include a unique telemetry marker allowing it to be readily distinguished from other satellites or space objects." Additionally, the Commission seeks comment on whether "there are hardware or information sharing requirements that might improve tracking capabilities, and whether such technologies are sufficiently developed that a requirement for their use would be efficient and effective."[19]

KTi has an existing solution that is capable of deployment addressing the complex tracking issues associated with satellite mega-constellations, as well as individual or smaller constellations of spacecraft. KTi's solution is also capable of tracking CubeSats, the very issue the Commission identifies as presenting "unique tracking and identification challenges."[20] KTi's Space Beacon approach will provide SSA data subscription services to commercial, defense and civil space agencies. Unlike existing current commercial SSA subscription services, KTi will provide explicit object identification and more frequent and timely updates than current remote sensing based SSA solutions.[21]

Cooperative tracking with explicit identification independent of main spacecraft systems should be required similar to the use of "black boxes" in aviation. Even with the ultrahigh

[18] Orbital Debris Mitigation, 33 FCC Rcd at 11365-66, para. 36.

[19] *Id.*

[20] *Id.*

[21] Letter from Keplerian Technologies Inc., to Marlene H. Dortch, Secretary, FCC, IB Docket No. 18-313, at 8 (filed Mar. 7, 2019).

reliability systems in place on today's sea and air systems, independent transponders offer security and transparency across national boundaries and in international lanes of commerce. Emphasizing this conclusion, the United Nation's Inter-Agency Space Debris Coordination Committee recommends "enhanc[ing] trackability [of small satellites] by adding onboard active and/or passive components."[22] KTi is developing hardware solutions with a first-generation beacon fully qualified for flight in 2019. Variations of the beacons will be available depending on the orbit to address lifetime issues as well as future generations with enhanced capabilities. With increasing congestion and orbital debris the "new normal," it is critically important for the Commission to lead the industry to proactive technological solutions that will enhance the value of space for all market participants. One essential component to making space safer for all market participants – commercial, government, and military actors – is to mandate the use of an independent transponder solution, like that offered by KTi, which promises to improve vastly SSA to the benefit of all.

IV. THE COMMISSION SHOULD MINIMIZE DATA SHARING TO INCLUDE ONLY ESSENTIAL DATASETS

The Commission seeks comment on whether NGSO operators should be required "to maintain ephemeris data for each satellite they operate and share that data with operators of other systems operating in the same region of space, as well as with the U.S. governmental entity responsible for the civilian space object database and cataloging."[23] The Commission further proposes requiring operators share "ephemeris data with any other operator identified in its

[22] U.N. Inter-Agency Debris Coordination Committee, *IADC Statement on Large Constellations of Satellites in Low Earth Orbit*, pg. 8, section 4.3.5, IADC-15-03 (Sept. 2017).
[23] Orbital Debris Mitigation, 33 FCC Rcd at 11377, para. 73.

disclosure described above of any operational space stations that may pose a collision risk."[24] As the Commission highlights, sharing such data would assist with collision avoidance.[25]

KTi agrees that enhanced data sharing would assist in collision avoidance. However, the Commission must not ignore the proprietary rights associated with data generated by spacecraft or their associated transponders. The Commission is well aware of the capital investment that operators make in designing and launching spacecraft, assembling constellations, and operating satellite-based networks. Data generated by spacecraft are confidential and proprietary information. The Commission must not sacrifice the transponder provider and satellite operators' business plans at the altar of safety when it is possible to narrow the requisite datasets to data essential for collision avoidance. KTi recommends that the Commission limit any data sharing obligations to satellite-state data. Three-dimensional position and velocity data is all that is required for purposes of collision avoidance. Data beyond this should be considered proprietary to the satellite operators and transponder service providers. Mandating more extensive sharing could have negatively impact operators' and service providers' business models. Moreover, limiting data sharing as proposed by KTi would be consistent with the data sharing practices of the airborne (ADS-B) and maritime (AIS) communities.[26]

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[24] *Id.*

[25] *See id.*

[26] *See* 14 CFR § 91.225 (requiring the use of ADS-B equipment on aircraft); FAA, *Automatic Dependent Surveillance-Broadcast (ADS-B)* (Mar. 12, 2019), https://www.faa.gov/nextgen/programs/adsb/ (FAA explaining ADS-B tracking and data sharing for aircraft); 33 CFR §164.46 (requiring the use of AIS equipment on marine craft); Navigation Center, United States Coast Guard, United States Department of Homeland Security, *AIS Frequently Asked Questions* (Mar. 20, 2019) https://www.navcen.uscg.gov/?pageName=AISFAQ (Coast Guard explaining AIS tracking and data sharing for marine craft).

V. KEPLERIAN'S SOLUTION COULD MITIGATE COLLISIONS AND LOWER INSURANCE PREMIUMS

The Commission is also seeking comment on issues related to damages and liability.[27] Along with the direct cost of the loss in property resulting from satellite collisions, there are real risks of damages and liability claims resulting from loss of revenue or commercial market share. These claims can quickly surpass the cost of a single satellite system. The law with respect to damages and liability is both outdated and immature. The 1972 Liability Convention ("Convention") establishes that parties are "absolutely" liable to pay compensation for damage caused by space objects to property on earth or to aircraft in flight. Additionally, the Convention provides for "fault-based" liability when causing damage to other space objects. Compliance with applicable domestic law by a satellite operator is not a defense if compliance with such law causes damages to another nation's space objects.

The lack of reasonable measures to prevent on-orbit satellite collisions on the part of spacecraft operators could provide justification for future "fault-based" claims in the cases of damages and liability disputes over orbital collisions. While not an issue for more traditional spacecraft operators, new small satellite systems have little to no capability to maneuver in order to prevent a potential orbital collision. While some mega-constellation companies have considered collision-avoidance maneuvering into their system design, most small satellites will continue to have no maneuvering capability for the foreseeable future. Accordingly, the enhanced SSA enabled by KTi's Space Beacons could provide the basis for laws that more accurately assess fault and damages rather than the imprecise, strict liability standard that exists today greatly increasing risks and insurances costs and risks to businesses and government, as the default insurer, alike.

[27] *See Orbital Debris Mitigation,* 33 FCC Rcd at 11378-80, paras. 76-81.

KTi's Space Beacons also provide an alternative or supplement to maneuvering systems through active broadcasting. Similar to modern maritime and airborne collision avoidance systems, KTi's Space Beacons will allow satellite operators to prove that they initiated reasonable measures to prevent or to limit orbital collisions in the event of liability disputes. As such, the satellite insurance industry has taken note of the significant growth in LEO satellites and operators and has begun to reassess current and future risk models. Leading U.S. insurance underwriters have noted that due to the increased population and density within the LEO operating environment, they anticipate an increase in third party insurance premiums. Discussions with these leading U.S. space insurance underwriters have validated that it would be reasonable to assume that third party liability insurance premiums would decrease or at least not increase if a spacecraft operator employed an automated position reporting capability such as that available through KTi's Space Beacons solution.

Requiring satellite operators to employ solutions, like that offered by KTi, would provide visibility into collision causation and greatly assist in assessing liability in the first instance as well as providing crucial data in the event of litigation. There is no judicial precedent relevant to resolving liability issues associated with satellite collisions as there has never been a collision between spacecraft controlled by two separate commercial satellite operators. Legal issues with respect to venue, choice of law and liability theories remain unknown. Regardless of resolution of many of these important issues, "black box" data provided by an independent transponder will clearly be essential to resolving any of these disputes. Also, utilizing solutions like KTi's could evolve to be an established "best practice" allowing operators to manage their costs of insurance, improve their operations and avoid collisions in the first place.

Relatedly, the Commission seeks comment on economic incentives that would help serve the policies identified in this proceeding.[28] KTi asserts that mandating operators maintain on-orbit and re-entry liability insurance would incentivize operators to reduce debris as well as collision risk. Requiring all operators to maintain insurance will allow the commercial insurance marketplace to manage risk in this area and remove governments from indemnifying operators. It will also encourage operators to deliberately consider risks, promote industry "best practices," incentivize the further development of technological solutions to avoid collisions, and reward firms that diligently evaluate risk and employ collision-preventive solutions to the benefit of all spacecraft operators and to the New Space marketplace and ecosystem. Accordingly, there are many reasons for the Commission to mandate insurance and doing so will support the important policies that this proceeding considers.

VI. NON-US LICENSED SATELLITES SEEKING ACCESS TO THE U.S. MARKET SHOULD BE SUBJECT TO THE COMMISSION'S RULES

The Commission seeks comment on whether any new rules adopted in this proceeding should apply to non-U.S.-licensed satellites seeking access to the U.S. market.[29] KTi supports subjecting such entities to any new rules adopted in this proceeding. Establishing a standard of conduct benefits all participants in space regardless of whether such operators are amateurs, commercial, military or government. Standardizing the rules of space and establishing guidelines for "space highways" and such new orbital lanes of commerce is essential to the space industry, national security, and the international communications network. Accordingly, all parties should follow the same rules that enhance the benefits of New Space.

[28] *Id.* at 11384, at para. 95.

[29] *Id.* at 11381-82, paras. 85-87.

VII. CONCLUSION

KTi applauds the Commission's decision to refresh its orbital debris rules, which were developed during an earlier and more staid era in the space industry. For the reasons stated herein, KTi urges the Commission to require commercial operators to employ onboard transponders to improve Space Situational Awareness, which will help protect the integrity and utility of increasingly congested orbits, and ultimately facilitate applications and analytics that mitigate collisions, improve satellite operator efficiency, and lower insurance premiums across the industry.

Respectfully submitted,

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